INDOOR AIR QUALITY ASSESSMENT

David Prouty High School
302 Main Street
Spencer, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response/Indoor Air Quality Program
June 2005

Background/Introduction

At the request of Mr. Ralph Hicks, Superintendent, Spencer/East Brookfield School District, the Massachusetts Department of Public Health's (MDPH), Center for Environmental Health (CEH) was contacted through Senator Stephen M. Brewer's Office to provided assistance and consultation regarding indoor air quality at the David Prouty High School (DPHS), 302 Main Street, Spencer, Massachusetts. On March 2, 2005, Cory Holmes, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an indoor air quality assessment. The assessment was prompted by reports of headaches and exacerbation of asthma that occupants believed to be attributed to building conditions.

The DPHS is a red brick building constructed in 1966, which consists of a three-story academic classroom wing and a single-story wing that contains common areas such as the cafeteria, shops, music room, auditorium, gymnasium and office space. No additions or major renovations have reportedly been made to the building. Windows are openable throughout the school.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-TRAK™ IAQ Monitor, Model 8551. CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The school houses approximately 600 students in grades nine through twelve with approximately 65 staff members. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) parts of air in thirty-two of forty-three areas surveyed, indicating inadequate air exchange in the majority of areas surveyed the day of the assessment. Fresh air in classrooms in the three-story academic wing is supplied by a unit ventilator (univent) system (Picture 1). Univents are designed to draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 2) and return air through an air intake located at the base of each unit (Figure 1). Fresh and return air are mixed and filtered, then heated and provided to classrooms through an air diffuser located in the top of the unit.

At the time of the assessment, a number of the univents were observed as deactivated, therefore no means of mechanical ventilation was being provided during the assessment. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns, were seen in a few classrooms (Picture 3). In order for univents to provide fresh air as designed, units must remain activated and allowed to operate while rooms are occupied. Intakes and return vents must also remain free of obstructions. Univents are also reportedly original equipment, which would make them approximately 40 years old. Univents of this age can be difficult to maintain because replacement parts are often unavailable.

Mechanical exhaust ventilation in the classroom wing is provided by unit exhaust ventilators (Picture 5). A unit exhaust ventilator appears similar to a univent, but removes air from the classroom and exhausts it out of the building (Picture 2). Unit exhaust ventilators were not operating in the majority of the areas surveyed at the time of the assessment. Mechanical exhaust ventilation for classrooms and specialty areas in the single-story wing are provided by grated wall vents powered by rooftop motors (Pictures 6 and 7). Several science classrooms had no exhaust ventilation capabilities (Table 1). Common areas (e.g., auditorium, gymnasium) were designed to be ventilated by air handling units (AHUs). The AHUs in the gymnasium were not operating during the assessment and the wall-mounted return vents were obstructed (Pictures 8 and 9). Without proper supply and exhaust ventilation, normally occurring environmental pollutants can build-up and lead to indoor air quality/comfort complaints, particularly in science classrooms during experiments or demonstrations.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools because a majority of occupants is young and considered a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from 66^{o} F to 81^{o} F, which were both above and below the MDPH recommended comfort guidelines in several areas during the assessment. The MDPH recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. Temperature complaints were expressed in a number of areas. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is often difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents, AHUs and exhaust ventilators not activated and/or obstructed).

The relative humidity ranged from 18 to 30 percent, which was below the MDPH recommended comfort range in all areas surveyed during the assessment. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A number of areas had water-stained, missing or damaged ceiling tiles (Table 1/Pictures 10 and 11), which can indicate leaks from the roof or plumbing system. Active leaks were reported in several areas of the single-story wing. School department officials are reportedly working with a roofing contractor to make repairs. Water-damaged ceiling tiles can provide a source for mold growth and should be replaced after a water leak is discovered and repaired. Missing and/or damaged tiles can provide a means for dust and particulates that accumulate in the ceiling plenum into occupied areas.

Other potential pathways for moisture to enter the building were identified. MDPH staff observed several areas where mortar around brick was missing and/or damaged (Pictures 12 and 13). Repeated water penetration can result in the chronic wetting of building materials and potentially lead to microbial growth. In addition, large cracks/holes in the exterior wall may provide a means of egress for pests/rodents into the building.

The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Plants were observed in several classrooms. Plants, soil and drip pans can serve as sources of mold growth. Plants should be properly maintained, over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants should be located away from ventilation sources to prevent aerosolization/entrainment of dirt, pollen or mold (Picture 14).

Other Concerns

A number of other conditions that can affect indoor air quality were noted during the assessment. Univents in several areas, including the cafeteria, had accumulated dust, cobwebs and debris within the air handling chambers and on filters. Window-mounted air conditioners (ACs) were installed in several areas. These units are normally equipped with filters, which should be cleaned or changed as per the manufacturer's instructions. Dust can be irritating to eyes, nose and respiratory tract.

Also of note was the amount of materials stored inside classrooms. In classrooms a number of areas items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Finally, the wood shop contains a wood dust collection system (Picture 16) indoors. Since the wood dust collector is not designed to filter small diameter particles, the use of this machine without ducting outdoors can aerosolize wood dust to make it more readily inhaled. Wood dust is a fine particulate, which can be easily aerosolized and can be irritating to the eyes, nose, throat and respiratory system.

Conclusions/Recommendations

The conditions related to indoor air quality problems at the DPHS raise a number of issues. The general building conditions, maintenance, work hygiene practices and the condition/age of ventilation equipment, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further degrade indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons, a two-phase approach is required for remediation. The first consists of **short-term** measures to improve air quality and the second consists of **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers throughout the school.
2. Operate all ventilation systems that are operable throughout the building continuously during periods of school occupancy and independent of thermostat control. To increase airflow in classrooms, set univent controls to “high”.
3. Inspect exhaust motors and belts for proper function. Make repairs as necessary.
4. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
5. Examine the feasibility of providing general exhaust ventilation to science rooms with no exhaust capabilities.
6. Consider having ventilation systems re-balanced every five years by an HVAC engineering firm.
7. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate

arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

8. Ensure roof leaks are repaired and repair/replace any remaining water-stained, missing or damaged ceiling tiles. Examine areas above these tiles for microbial growth. Disinfect with an appropriate antimicrobial where necessary.
9. Move plants away from univents in classrooms. Avoid over-watering and examine drip pans periodically for mold growth. Disinfect with an appropriate antimicrobial where necessary.
10. Change filters for air-handling equipment (e.g., univents, AHUs, ACs and wood dust collector) as per the manufacturer's instructions or more frequently if needed. Vacuum interior of units prior to activation to prevent the aerosolization of dirt, dust and particulates. Ensure filters fit flush in their racks with no spaces in between allowing bypass of unfiltered air into the unit.
11. Clean univent interiors, return vents and exhaust vents periodically of accumulated dust.
12. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
13. Consider developing a written notification system for building occupants to report indoor air quality issues/problems. Have these concerns relayed to the maintenance

department/ building management in a manner that allows for a timely remediation of the problem.

14. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.

15. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

The following **long-term measures** should be considered:

1. Consider contacting an HVAC engineering firm to fully evaluate the ventilation systems building-wide. Based on the age, physical condition and availability of parts for ventilation components, this measure is strongly recommended.
2. Consider relocating wood dust collection system outdoors or in a shelter separated from occupied areas and ducted to the outside.

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. Code Administrators International, Inc., Country Club Hill, IL.

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials and Code Administrators International, Inc., Country Club Hill, IL. Section M-308.1.1.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0

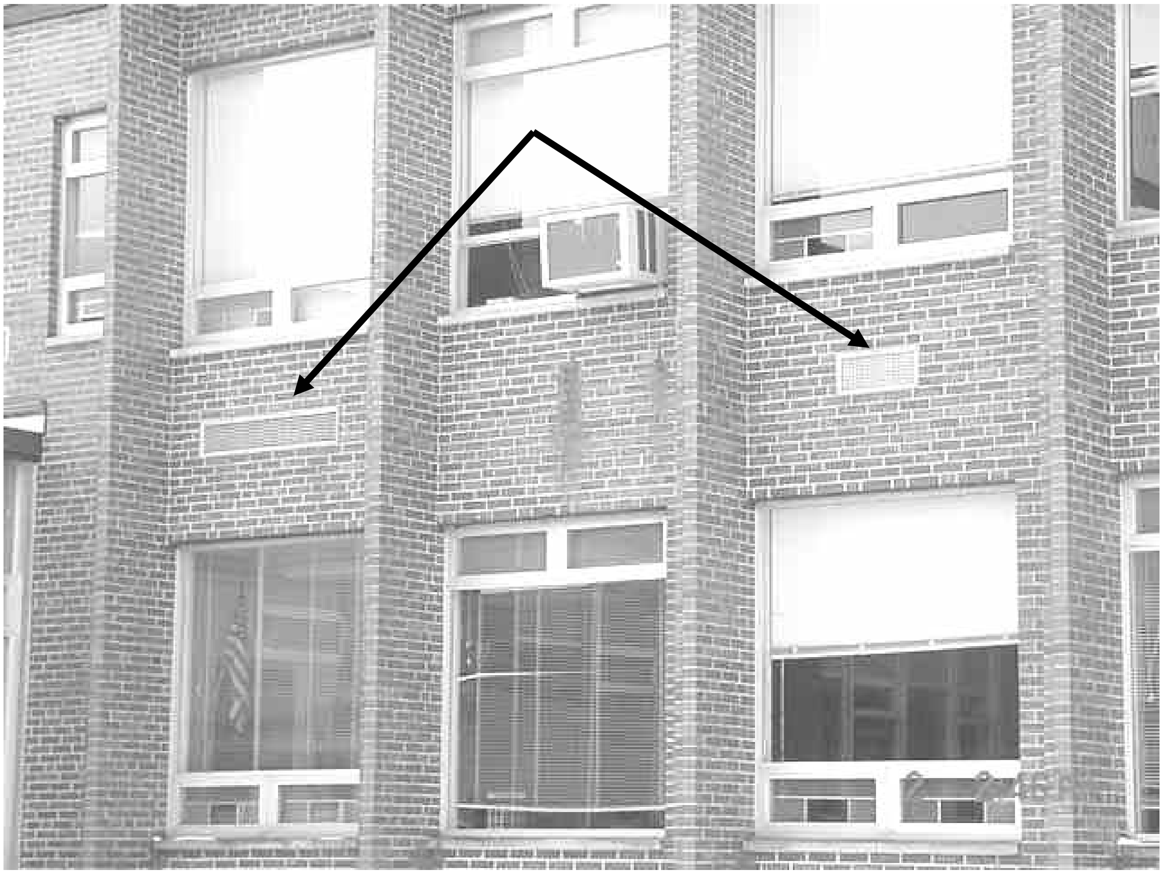
SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 2001. Mold Remediation in Schools and Commercial Buildings. US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, D.C. EPA 402-K-01-001. March 2001.

Picture 1

Classroom Univent

Picture 2



Univent Air Intakes (larger vents on left) and Unit Exhaust Ventilator Vents (small vents on right)

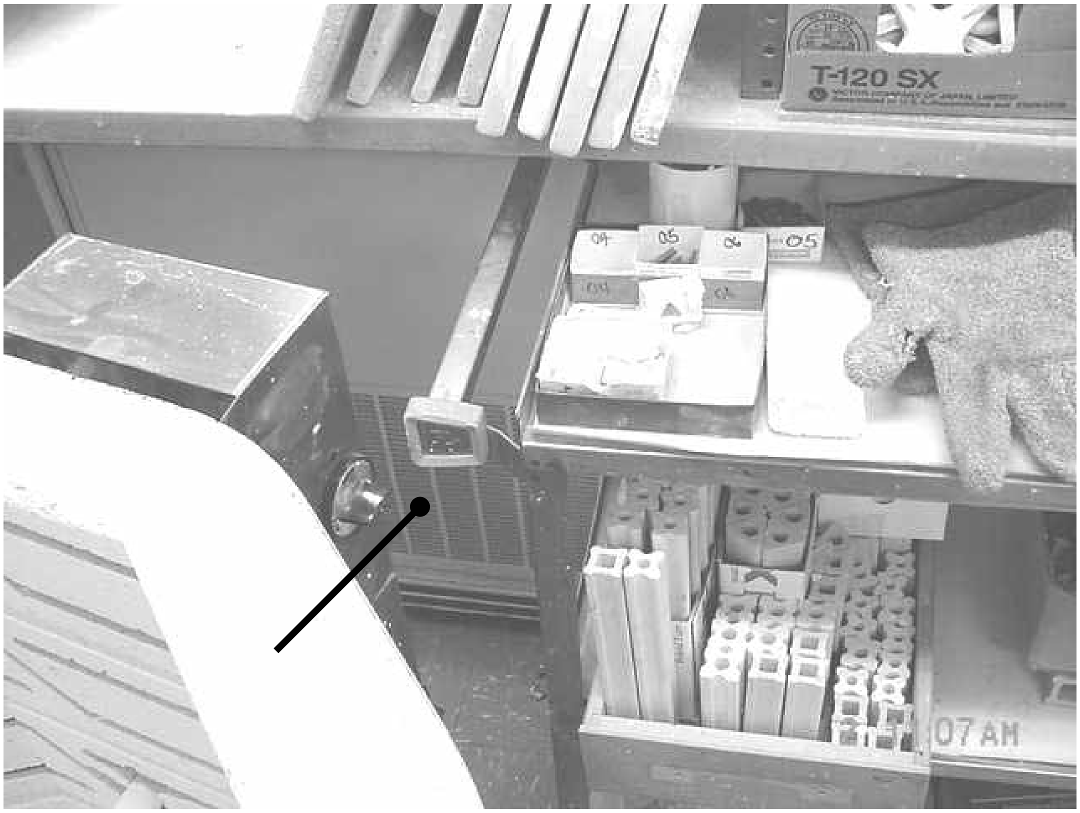
Picture 3

Univent in Art Room Obstructed by Materials

Picture 4

Unit Exhaust Ventilator

Picture 5



Unit Exhaust Ventilator Obstructed by Various Items

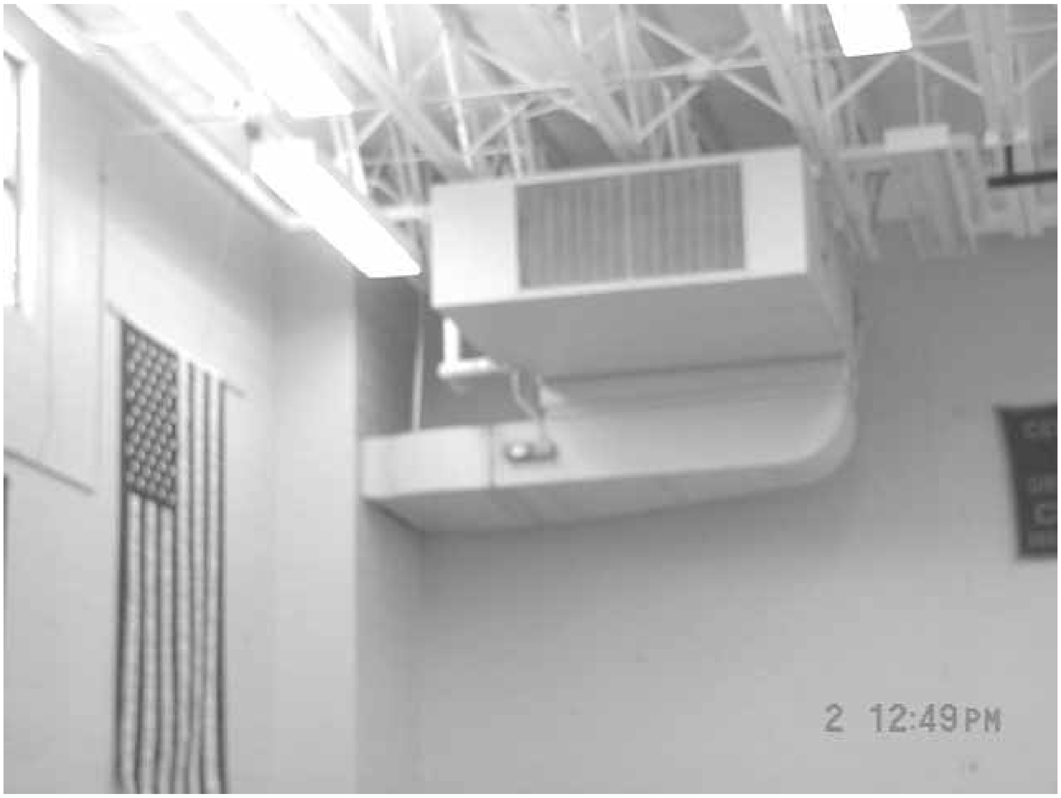
Picture 6

Wall-Mounted Exhaust Vent

Picture 7

Rooftop Exhaust Motors

Picture 8

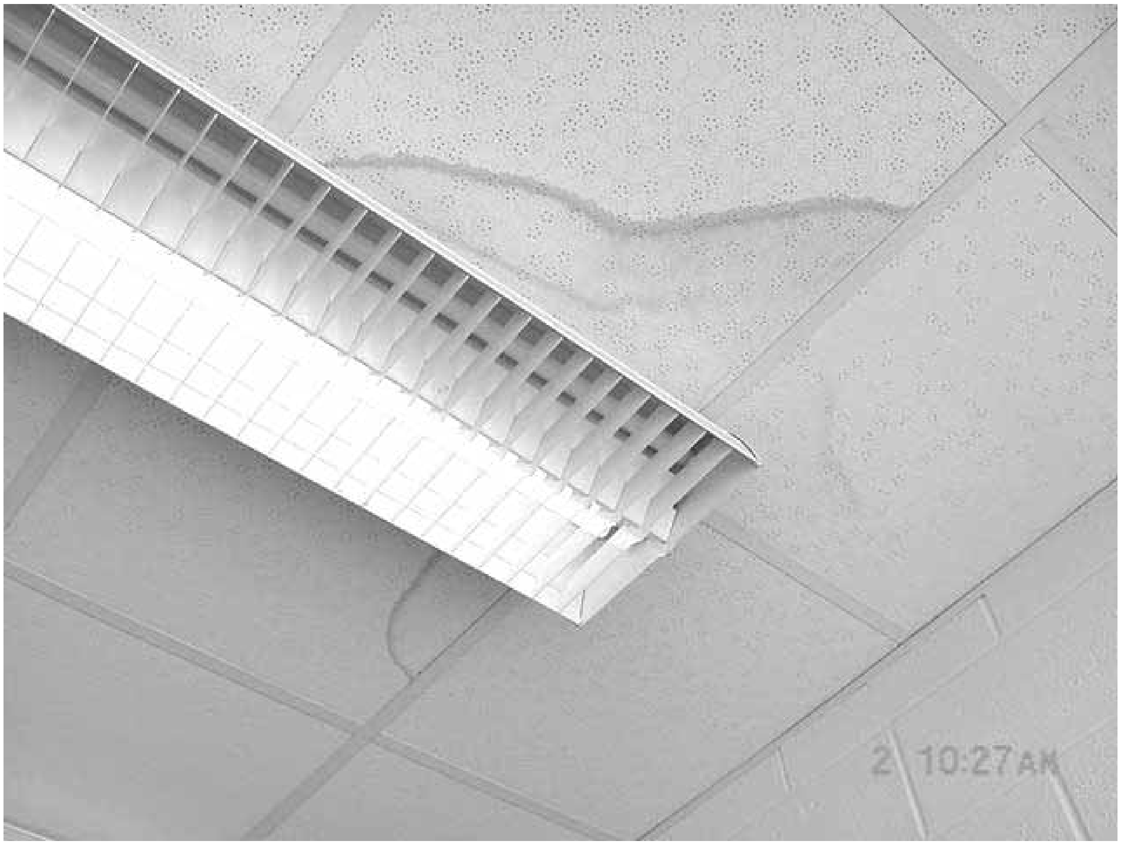


Ceiling-Mounted AHU in Gymnasium

Picture 9

Gymnasium Exhaust/Return Vent Obstructed by Gym Mat

Picture 10

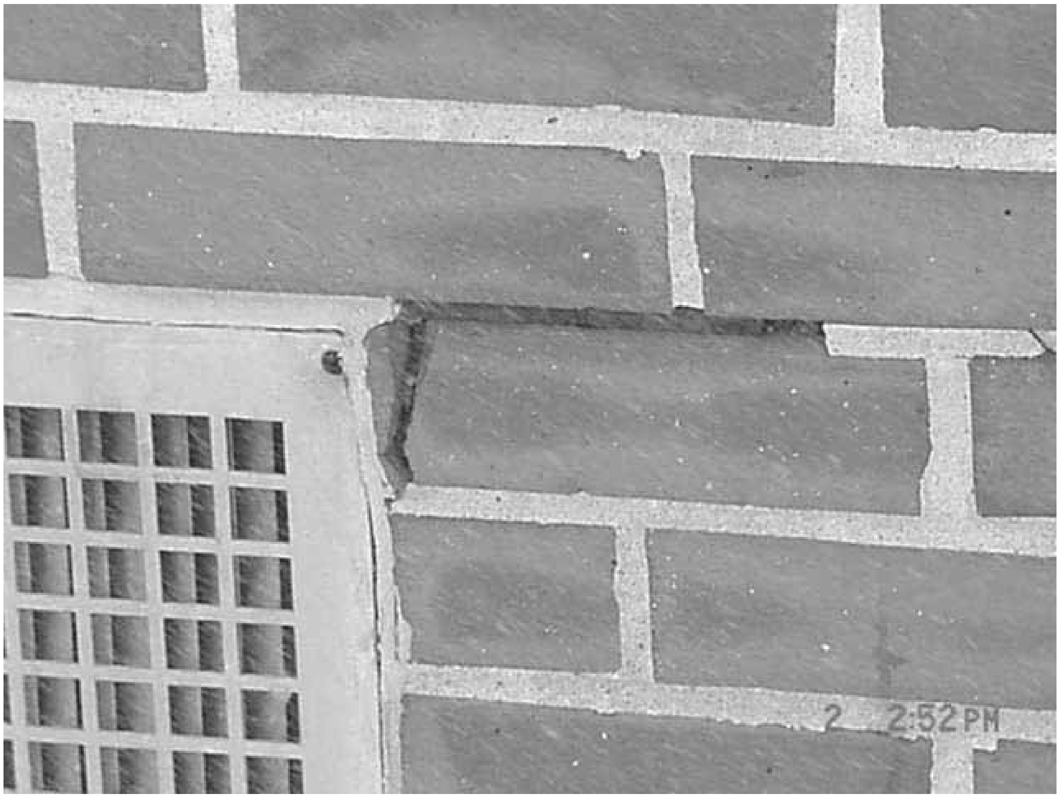


Water Damaged Ceiling Tiles

Picture 11

Water Damaged Ceiling Tiles

Picture 12



Missing/Damaged Mortar around Exterior Brick

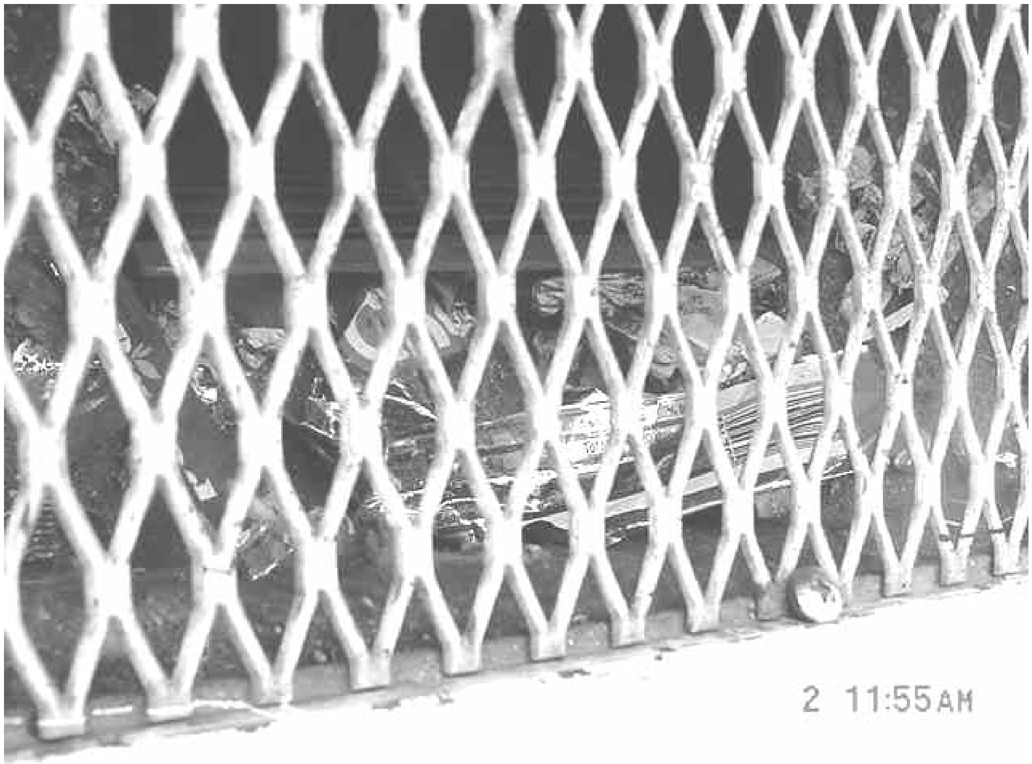
Picture 13

Missing/Damaged Mortar around Exterior Brick

Picture 14

Plants in Classroom near Univent Air Diffuser

Picture 15



Trash/Debris inside Univent Air Diffuser

Picture 16

Wood Dust Collection System inside Woodshop

TABLE 1

Indoor Air Test Results – Prouty High School, 302 Main Street, Spencer, MA – March 2, 2005

Location	Carbon Dioxide (*ppm)	Temp (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background	307	32	27					Mostly cloudy, cold, NW winds 10-15 mph
Main Hallway								WD CTs
Boiler Room								Door propped open
Auditorium	721	68	21	~40	N	Y	Y	Ceiling air diffusers, wall exhaust vents
Art Room	2401	72	30	16	Y	Y	Y	UV return obstructed, accumulated items, exhaust off, 1 dislodged CT, 2 WD CTs
315	1388	69	26	23	Y	Y	Y	Materials/debris in UV, UV and exhaust off, DO
314	1516	71	27	24		Y	Y	UV and exhaust off (deactivated), DO
313	1283	70	23	12	Y	Y	Y	DO, 3 WD CT, exhaust off

- **ppm = parts per million parts of air,**
- **DO = door open,**
- **WD CT = water damaged ceiling tile**
- **UV = univent**
- **DEM = dry erase markers**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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						Supply	Exhaust	
302	1103	71	23	15	Y	Y	Y	Exhaust off, DEM
312	1606	73	25	13	Y	Y	Y	UV-loud noise (fan), exhaust off
303	1276	73	23	13	Y	Y	Y	DO, exhaust off, window AC, DEM
311	1338	72	24	17	Y	Y	Y	DO, UV-noise (rattle), exhaust off-backdrafting, DEM-particulates
304	2004	73	28	27	Y	Y	Y	Exhaust off, 6 WD CT
310	1180	73	23	0	Y	Y	Y	~24 occupants at lunch 1 min, UV-noise, 2 dislodged CTs
305	1832	74	27	1	Y	Y	Y	UV & exhaust off, window AC
306	1096	73	23	4	Y	Y	Y	UV off, exhaust blocked by chair, plants, photocopier, DO

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						Supply	Exhaust	
308	730	72	20	0	Y	Y	Y	Dislodged CT, broken window, UV and exhaust off
307	803	75	21	0	Y	Y	Y	4 WD CT, exhaust blocked by chairs, heat issues
Cafeteria	1094	74	23	~170	Y	Y	Y	Trash/debris in UV, 4 Uvs-2 off, exhaust off, numerous WD CTs
Faculty Lunchroom	628	74	20	2	N	Y	Y	Exhaust off, 15(+) WD CTs
Main Office	910	72	22	1	N	N	N	Photocopier, recommend passive vent into main hallway
Guidance	749	72	21	0	N	N	N	8 WD CTs, photocopier
206	756	70	22	3	Y	Y	Y	UV return vent blocked by couch, 3 WD CTs, 3 photocopiers (on wall opposite exhaust vent), exhaust off

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						Supply	Exhaust	
Nurse's Office	677	71	20	2	Y	N	N	2 WD CTs, bathroom exhaust vent not operating
209 Library	560	73	19	0	Y	Y	Y	Exhaust off, AC
210	1381	81	25	23	Y	Y	Y	Exhaust off, DO
211	865	75	18	17	Y	Y	Y	Plants, DO, DEM, plants, 10 WD CT, 1 missing tile, exhaust off
201	1466	74	29	22	Y	Y	Y	DO, no general exhaust, local exhaust fans
202	1120	72	23	0	Y	Y	Y	Exhaust off, plants
203	734	72	18	1	Y	Y	Y	~20 occupants gone 15 min, DO, missing CTs, exhaust off
204	643	73	18	0	Y	Y	Y	Exhaust off, 3 WD CTs, DEM, window open

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205	824	73	19	0	Y	Y	Y	DEM, DO, exhaust off, 20 + WD CTs
Gym	724	66	20	0	Y	Y	Y	2 ceiling-mounted AHUs-off, exhaust vents obstructed
Biology	1164	68	24	7	Y	Y	N	No general exhaust ventilation
104	1767	70	28	25	Y	Y	Y	10 = WD CTs, birds near air stream of UV
106	885	71	21	19	Y	Y	Y	DEM, exhaust off, DO
107	1226	71	23	14	Y	Y	Y	Exhaust off, DO
108	1307	71	24	18	Y	Y	Y	DO, exhaust off, DEM
109	1208	72	23	21	Y	Y	Y	DO, DEM, 1 WD CT
110	1068	73	23	14	Y	Y	Y	DO, 3 WD CTs, exhaust off, DEM

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						Supply	Exhaust	
111	827	71	20	9	Y	Y	Y	6 WD CT, exhaust off, DEM
101	1790	74	28	20	Y	Y	N	Plants, window mechanism broken, no general exhaust
103	1645	73	25	18	Y	Y	N	10 + WD CTs, no general exhaust
Wood Shop	853	73	22	11	Y	Y	Y	UV deactivated, general exhaust blocked by tool cabinet
Tech Ed	933	74	24	20	Y	Y	Y	Exhaust blocked by cabinet, wood dust collector inside
Music	629	73	18	7	Y	Y		DEB, DO

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